

Climate Change

**A MULTIDISCIPLINARY
APPROACH**

WILLIAM JAMES BURROUGHS



CAMBRIDGE
UNIVERSITY PRESS

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge, CB2 2RU, UK <http://www.cup.cam.ac.uk>
40 West 20th Street, New York, NY 10011-4211, USA <http://www.cup.org>
10 Stamford Road, Oakleigh, Melbourne 3166, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain

© Cambridge University Press 2001

This book is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of Cambridge University Press.

First published 2001

Printed in the United States of America

Typeface Melior 9.75/13 and Eurostile System 3B2 [KWP]

A catalog record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Burroughs, William James

Climate change : a multidisciplinary approach / William James Burroughs.

p. cm.

ISBN 0-521-56125-6 – ISBN 0-521-56771-8

1. Climate changes. I. Title.

QC981.8.C5 B86 2001 00-033750

551.6–dc21

ISBN 0-521-56125-6 hardback

ISBN 0-521-56771-8 paperback

CONTENTS

<i>Preface</i>	<i>page</i> ix
<i>Acknowledgements</i>	xiii
<i>List of Boxes</i>	xv
1 INTRODUCTION	1
1.1 Weather and Climate	2
1.2 What Is Climate Variability and Climate Change?	2
1.3 Connections, Timescales and Uncertainties	3
2 RADIATION AND THE EARTH'S ENERGY BALANCE	10
2.1 Solar and Terrestrial Radiation	11
2.1.1 Radiation Laws	11
2.1.2 Solar Radiation	15
2.1.3 Terrestrial Radiation	15
2.1.4 The Energy Balance of the Earth	20
2.2 Solar Variability	27
2.3 Summary	30
3 THE ELEMENTS OF THE CLIMATE	32
3.1 The Atmosphere and Oceans in Motion	32
3.2 Atmospheric Circulation Patterns	36
3.3 Radiation Balance	45
3.4 The Hydrological Cycle	49
3.5 The Biosphere	50
3.6 Sustained Abnormal Weather Patterns	51
3.7 Atmosphere–Ocean Interactions	56
3.8 The Great Ocean Conveyor	67
3.9 Summary	71
4 EVIDENCE OF CLIMATE CHANGE	73
4.1 Peering into the Abyss of Time	74

CONTENTS

4.2	Atmospheric Composition	85
4.3	Sea Level Fluctuations	87
4.4	The Ice Ages	90
4.5	The End of the Last Ice Age	95
4.6	The Holocene Climatic Optimum	98
4.7	Changes in Recorded History	100
4.8	The Medieval Climatic Optimum	104
4.9	The ‘Little Ice Age’	104
4.10	The Twentieth Century Warming	110
4.11	Concluding Observations	113
5	CONSEQUENCES OF CLIMATE CHANGE	116
5.1	Geological Consequences	117
5.2	Flora and Fauna	118
5.3	Mass Extinctions	122
5.4	Glaciers, Ice Caps, Ice Sheets and Sea Levels	123
5.5	The Historical Impact of Climatic Variations	126
5.6	Agriculture	128
5.7	Spread of Diseases	132
5.8	The Economic Impact of Extreme Weather Events	134
5.9	Summary	137
6	THE MEASUREMENT OF CLIMATIC CHANGE	139
6.1	Instrumental Observations	140
6.2	Satellite Measurements	146
6.3	Historical Records	151
6.4	Proxy Measurements	153
6.4.1	Tree Rings	154
6.4.2	Ice Cores	157
6.4.3	Ocean Sediments	161
6.4.4	Pollen Records	163
6.4.5	Boreholes	166
6.4.6.	Other Proxy Measurements	167
6.5	Dating	168
6.6	Isotope Age Dating	169
6.7	Summary	173
7	STATISTICS, SIGNIFICANCE AND CYCLES	175
7.1	Time Series, Sampling and Harmonic Analysis	176
7.2	Noise	180
7.3	Measures of Variability and Significance	182
7.4	Smoothing	193
7.5	Multidimensional Analysis	197
7.6	Summary	199

8 THE CAUSES OF CLIMATIC CHANGE	201
8.1 Autovariance and Non-linearity	202
8.2 Atmosphere–Ocean Interactions	204
8.3 Ocean Currents	207
8.4 Volcanoes	208
8.5 Sunspots and Solar Activity	211
8.6 Tidal Forces	217
8.7 Orbital Variations	221
8.8 Changes in Atmospheric Composition	225
8.9 Human Activities	227
8.10 Catastrophes and the ‘Nuclear Winter’	230
8.11 Summary	235
9 MODELLING THE CLIMATE	239
9.1 Global Circulation Models	240
9.2 Simulation of Climatic Variability	247
9.3 The Challenges Facing Modellers	252
9.3.1 Clouds	253
9.3.2 Land-Surface Processes	254
9.3.3 Winds, Waves and Currents	255
9.3.4 Other Greenhouse Gases	256
9.3.5 Exploitation of Numerical Weather Prediction	256
9.4 Summary	257
10 PREDICTING CLIMATE CHANGE	259
10.1 Natural Variability	259
10.2 Predicting Global Warming	261
10.3 The Predicted Consequences of Global Warming	263
10.4 When Will We Be Certain About Global Warming?	267
10.5 Can We Do Anything About Climate Change?	271
10.6 The Gaia Hypothesis	273
<i>Bibliography</i>	277
<i>Glossary</i>	283
<i>Index</i>	293

LIST OF BOXES

Box 1.1	The nature of feedback	6
Box 2.1	The Greenhouse Effect	13
Box 2.2	Photochemical processes	18
Box 3.1	Thermohaline circulation	68
Box 6.1	Information from isotope ratios	156
Box 6.2	Radioactive isotope dating	170
Box 6.3	Accuracy of carbon dating	171
Box 7.1	Meteorological time series and variance	177
Box 7.2	Interpretation of correlation coefficients	185
Box 7.3	Sherman's statistic	190
Box 8.1	Is the climate chaotic?	202